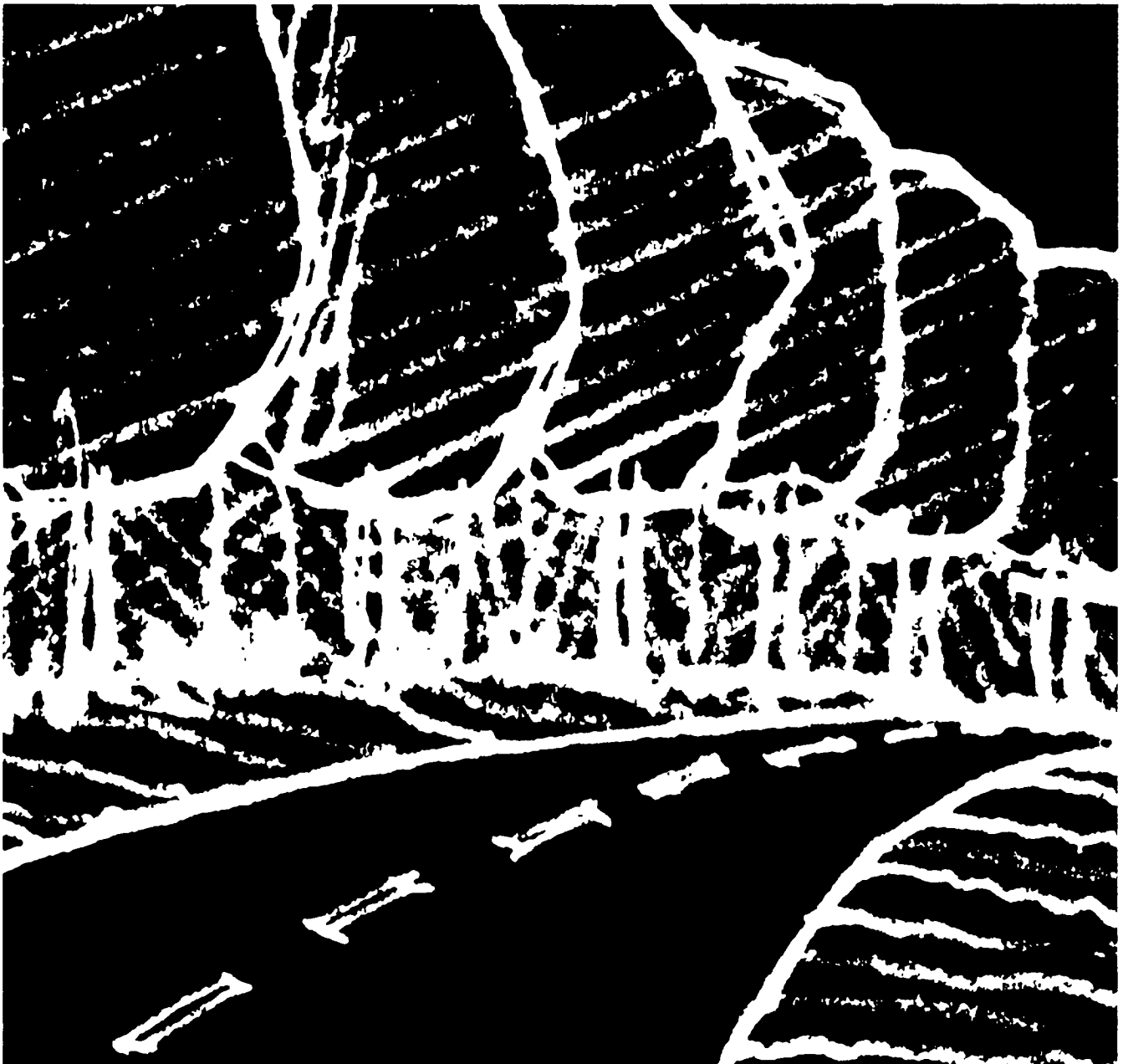


The vehicular circulation system provides not only a primary means of on-site access but also a primary vantage point along which people see an installation. In most cases, the road network is historically predetermined. While the existing road network may be functionally deficient, it may be costly and difficult to change because of the land uses, buildings

and utilities which have been located in response to its alignment. However, much can be done to improve the road network, both functionally and visually. Functionally, a hierarchical network can be created that separates incompatible types of traffic and promotes energy efficiency. Visually, this hierarchy can be reinforced to promote a better

comprehension, sense of orientation and ease of circulation for the motorist as well as a more attractive streetscape. (For guidance on road construction details and geometric design criteria, see *TM 5-822-2*; *AFM 88-7, Chapter 5*; and *NAVFAC DM-5 Series*.)



Observations and Objectives.

4-1.

Typical Problems.

A. Road Network.

Most installations typically have a grid network of streets. However, strict adherence to this grid network often neglects natural site features and can constrain building design and expansion capabilities. Sometimes the grid system is combined with a curvilinear pattern of streets which can result in visual as well as functional problems in understanding the circulation system.

B. Circulation Hierarchy.

Various classification systems exist defining different functions that a road performs, i.e., primary, secondary, tertiary. It is desirable that road rights-of-way, pavement widths, speed limits, provisions of curbs and sidewalks, street lighting, street trees, traffic and parking controls, and other characteristics be varied to reflect and facilitate the functions that the road performs. This is often not the case on installations where undifferentiated networks result in a variety of problems such as through-traffic on local residential streets. In many cases a sense of the road hierarchy does not exist or has not been visually reinforced, resulting in an unclear system as well as unnecessary street segments.



fig. 4-1.

C. Intersections and Traffic Controls.

The grid network, most prevalent on installations, results in a maximum number of four-way intersections and necessitates a greater dependency on signalization and other traffic control devices. There has been inadequate consideration of the pedestrian and his safety where vehicular and pedestrian networks interface (*fig. 4-1*).

D. Channelization.

A common problem on military installations is unsafe and unsightly techniques for channeling vehicles, such as poles or guardrails mounted in the road pavement without protective curbing (*fig. 4-2*). The need for these devices is most often the result of improper intersection



fig. 4-2.



fig. 4-3.

design, but when necessary, their design need not be unsafe to motorists. In other cases where medians are used for channelization, planting that requires a high amount of maintenance or unattractive paving techniques are common, despite the availability of attractive but relatively maintenance-free plant materials that could be used.

E. Curbs and Gutters.

The incremental construction of curbs and gutters is typical at installations and often results in awkward transition areas (*fig. 4-3*).

4-2.

Objectives.

A. Circulation System.

The circulation system should define a hierarchy of flow from the installation entrance to major and minor roads leading to specific destinations. A clearly structured and consistent circulation system can provide coherence to the overall installation. If visually reinforced, the system can simplify driver decisions, decrease motorist confusion, and provide a level of visual continuity and cohesiveness to the installation.

B. Adapt Roads to Site Conditions.

New road alignments should relate to the natural contours of the land in order to minimize grading and disruption of the natural environment. Within developed areas, planting, screening, setbacks and other techniques can be used to visually integrate roads with the land use areas that they serve. All necessary signs and coordinated site furnishings should be employed to enhance the streetscape.

C. Improve the Existing Network for Growth, Safety and Appearance.

1. Growth. Closely spaced grid street systems that are underutilized may provide the opportunity to create large facility development areas through the closing of unnecessary streets.

2. Safety and Appearance.

The clarity of a circulation system promotes safety for its users. The confused driver slowing down at intersections or finding himself in the wrong lane near his destination increases the likelihood of causing an accident. Intersection details, sight lines and traffic control devices are all important safety-related considerations.

A clear and unconfusing circulation system is also less cluttered and thereby more attractive to its users.

3. Maintenance and Repair.

Roads occupy a large percentage of the total land area of an installation, especially in dense developments. The design and detailing of roads should facilitate cleaning, snow removal and other associated maintenance and repair operations. Planting of shoulders and medians should be of appropriate low maintenance plant materials.

Section II:

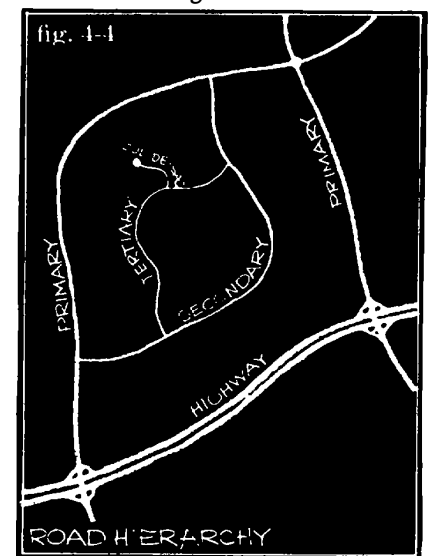
Design Guidelines

4-3.

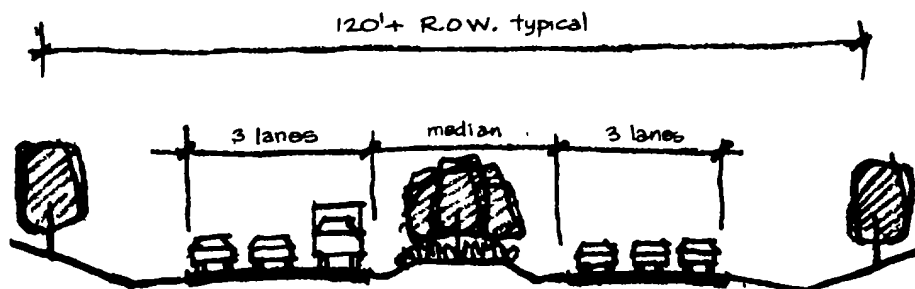
Establish a Coherent Road Network Hierarchy.

The road network of an installation should functionally and visually reflect a logical hierarchy of traffic circulation. The network should separate types of traffic by function, ranging from through-traffic to local traffic. The visual character of each segment of the network should appropriately

fig. 4-4.



convey its role and function within the overall network (*fig. 4-4*). The basic hierarchy of the network can be generally classified as follows in terms of the type, character and appearance of roads.



HIGHWAY
Fig. 4-5.

A. Highways.

Highways provide primary high-speed traffic access to, around or through a military installation (fig. 4-5). Design characteristics of highways include:

1. Continuous, relatively straight or large radii curvilinear alignments that carry high speed through-traffic movement between major activity centers within the region.
2. A minimum of two lanes in each direction, typically divided by a median or median barrier.
3. Alignments that border land use areas rather than bisect them, and greenspace buffers between the road and adjacent uses.
4. Controlled access onto the road.
5. Either grade-separated or at grade channelized intersections with traffic signal controls.
6. Shoulders for emergency stopping but strict prohibition of on-street parking.
7. Street signing, lighting and planting that reflect the high speed nature of traffic movement.

B. Primary.

These roads provide the network connecting major activity centers within the installation (fig. 4-6). Design characteristics include:

1. Continuous, through-traffic alignments that are relatively straight or large-radii curvilinear to handle moderate-to-high speed traffic.

Fig. 4-6.

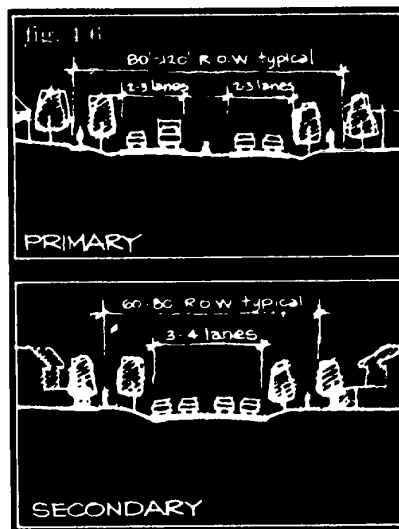


Fig. 4-7.

2. Alignments that form the boundary between different land use areas rather than bisect an area.
3. Two to three moving lanes in each direction, typically divided by a median.
4. Controlled access and a minimum of curb cuts limited to entrance-ways to major facilities or building groups.

5. At-grade channelized intersection with traffic signal controls.

6. On-street parking prohibited.

7. Adjacent sidewalks separated from the road by sizable planting strip.

8. Medians, street lighting, signing and planting that reinforce the moderate-to-high speed nature and importance of the road.

C. Secondary.

These roads provide the means of traffic movement between primary and tertiary roads (fig. 4-7). Design characteristics include:

1. Continuous through-traffic alignments between primary roads, either straight or curvilinear based

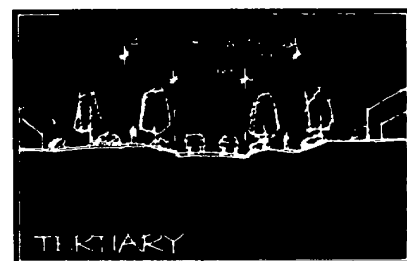


Fig. 4-8.

upon the desired design speed, topography and land use pattern.

2. Direct access to abutting property.
3. A maximum of two moving traffic lanes in each direction, either undivided or a boulevard with planted median.
4. On-street parking generally prohibited.
5. Sidewalks separated from the road by a planting strip.

6. Street lighting, signing and planting that reflect the moderate-to-slow speed nature of traffic and the character of the land use area they are within.

D. Tertiary.

These roads handle local traffic movement from secondary streets and provide direct access to abutting property (*fig. 4-8*). Design characteristics include:

1. Discontinuous alignments, except between secondary streets, to discourage through traffic.
2. Relatively short, straight or smaller radii curvilinear alignments in keeping with topography, land use and slow speed nature of traffic.
3. Generally a maximum of two moving traffic lanes, one in each direction.
4. On-street parking allowable on an infrequent overflow basis by the addition of a parallel parking lane or bay.
5. Curbs, gutters and sidewalks generally provided in residential areas with densities greater than two dwelling units per acre; sidewalks may be limited to only one side, depending upon need.
6. Street lighting, signing and planting in character with the slow speed nature of traffic and the land use area within which the road is located.

E. Cul-de-sacs.

These are short dead-end tertiary streets, primarily in residential areas. They connect at one end to a tertiary or secondary street and have a turnaround at their other end, providing direct access to abutting property while preventing through traffic. Design characteristics include:

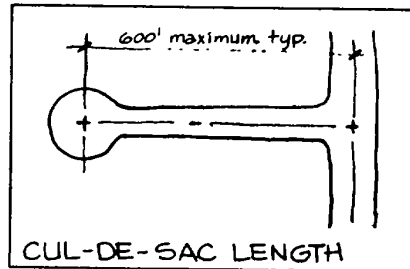


Fig. 4-9.

1. Short, straight or smaller radii curvilinear alignments that serve abutting property.
2. Generally a maximum of two traffic lanes, one in each direction.
3. Generally a maximum length of 600 feet, except in areas where terrain and low density development indicate a longer length, which in no case should exceed 1200 feet or 20 dwelling units, whichever is the lesser (*fig. 4-9*).
4. Turnarounds generally 70 to 90 feet in diameter at their ends to accommodate not only cars, but also fire and garbage trucks (*fig. 4-10*); turnarounds can be either symmetrical or offset; turnarounds can have center planting islands to reduce the expanse of paved area at the turnaround.

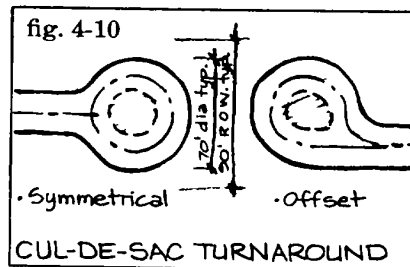


Fig. 4-10.

5. Infrequent over-spill parking can be provided on street by either parallel parking bays or within center island area of over-sized turnarounds.

6. Sidewalks, if any, are generally limited to one side of the road.

7. Street lighting, signing and planting in character with the slow speed nature of traffic and the land use area being served.

F. Other Roadway Types.

The vehicular circulation system of an installation can also contain several other types of roadways including rural roads and patrol roads.

1. **Rural Roads.** These roads are for traffic through sparsely developed areas of the installation (*fig. 4-11*). Design characteristics include:

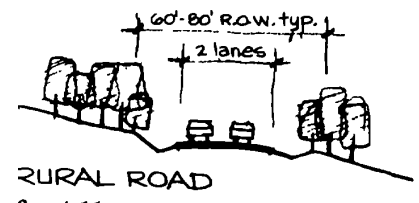


Fig. 4-11.

- a. Generally two traffic lanes, one in each direction, with emergency pull-off shoulders.
- b. Curbs and on-street parking generally not provided.
- c. Street lighting generally not provided except at intersections.
- d. Planting in character with the design speed and natural landscape character of the alignment; storm drainage in swales or ditches that blend into the natural landform.

2. **Service Roads.** These roads provide for service traffic only to adjacent buildings. Design characteristics include:

- a. A maximum pavement width of 18 to 20 feet.
- b. Continuous alignment between tertiary streets.
- c. A possible location for overhead utility service to buildings.

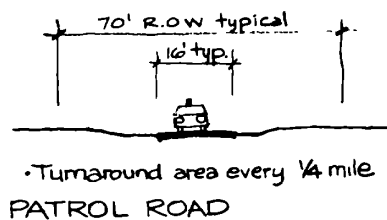


Fig. 4-12.

3. Patrol Roads. These are special roads for surveillance and security purposes that carry restricted, low volume vehicular traffic (fig. 4-12). Design characteristics include:

- a. Sixteen-foot wide road which may be paved without curbs and contoured to the natural landform.
- b. Turnaround lanes every 1/4 mile.

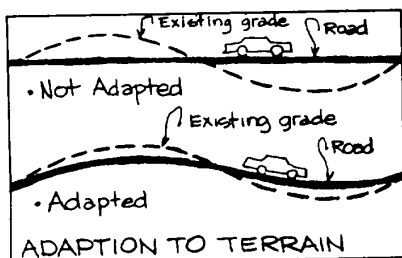


Fig. 4-13.

4-4.

Adapt Roads to Site Conditions.

New road alignments as well as improvements to existing roads should be harmonious with natural site conditions and the land use pattern of the installation. They should be designed to minimize negative environmental impacts, relieve driver monotony and provide a positive visual experience for the motorist.

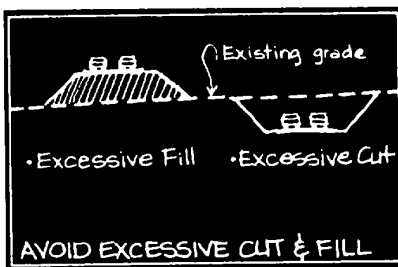


Fig. 4-14.

A. Blend Roads with the Natural Landform.

The horizontal and vertical alignment of roads should minimize landform disturbance and blend with the natural setting (fig. 4-14).

1. Minimize cut and fill slopes.
 - a. Avoid steep terrain that requires excess cut and fill to accommodate road alignments (fig. 4-14).
 - b. In rolling terrain, align roads to cross slopes diagonally or parallel to contours rather than perpendicular to contours (fig. 4-15).
 - c. Consider variable-width medians in rolling topography to minimize site disturbance (fig. 4-16). Medians can be used in this manner to reduce continuous pavement width, accommodate vertical grade differences between roadway surfaces within the median and preserve as much of the natural landform and vegetation as possible.
2. Mold cut and fill slopes to blend into the natural landform.

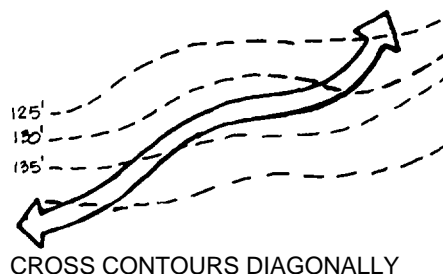


Fig. 4-15.

a. Round slopes to avoid creating sharp and unnatural slopes that contrast with the natural landform (fig. 4-17).

b. Warp slopes to become an extension of the natural landform by rounding them both horizontally and vertically (fig. 4-18).

c. Use excess excavation materials to create either mounds or fill areas that blend the road into the natural landform.



Fig. 4-16.

d. Use natural rock outcroppings as slope retaining elements (fig. 4-19). Form them in a natural way by random scarification when they must be partially removed to accommodate the road alignment.

3. Blend road drainage ditches, swales or channels into the natural landform.

a. Round the edges of road drainage ways to reduce contrasts with the natural landform (fig. 4-20).

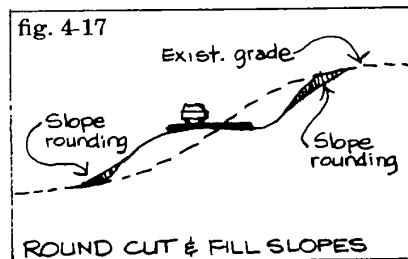


Fig. 4-17.

b. Vary the alignment of road drainage ways from that of the road according to the natural drainage system of the terrain, avoiding perfectly parallel alignments that are unnatural in appearance.

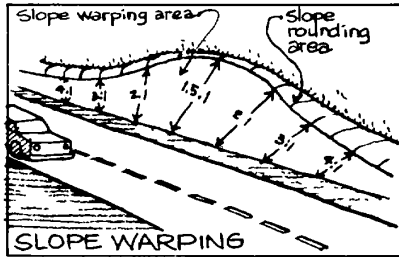


Fig. 4-18.

4. Consider the use of cluster development patterns since they minimize site disturbance as well as the costs of road development, especially in residential areas (fig. 4-21).

5. Utilize natural topographic conditions to create grade-separated pedestrian and bikeway road crossings.

a. At depressed road areas design overpasses connecting high points of natural terrain.

Fig. 4-19.

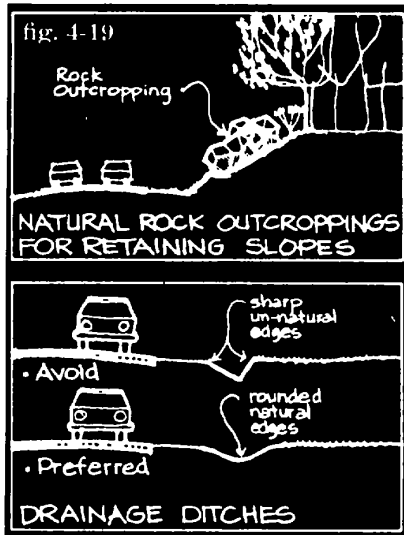
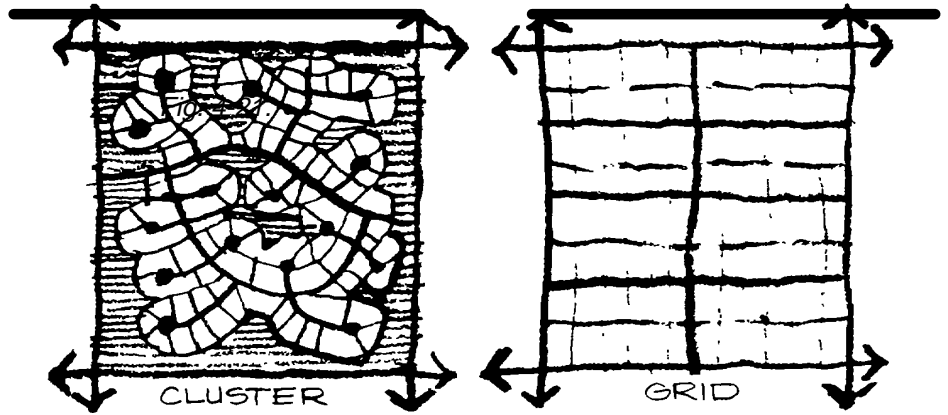


Fig. 4-20.

b. At elevated road areas design underpasses connecting low points of natural terrain (fig. 4-22).



B. Adapt Roads to the Natural Landscape Character.

Design roads to minimize disturbance to existing vegetation, to encourage revegetation in disturbed areas and to reduce the visual impact of landscape disturbance.

1. Minimize the amount of clearance of existing vegetation.

a. Align roads in open areas along the edge of forested areas, rather than through forested areas, whenever possible (fig. 4-23).

b. Carefully align roads to minimize earthwork, therefore reducing necessary clearing limits.

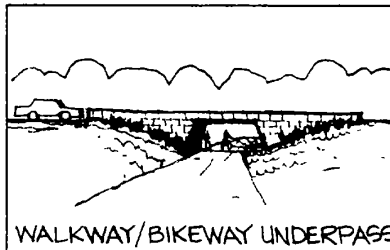


Fig. 4-22.

c. Clear only to the edge of necessary regrading or sight distance lines, rather than a uniform right-of-way clearance width (fig. 4-24).



Fig. 4-23.

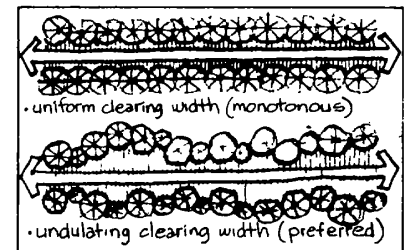


Fig. 4-24.

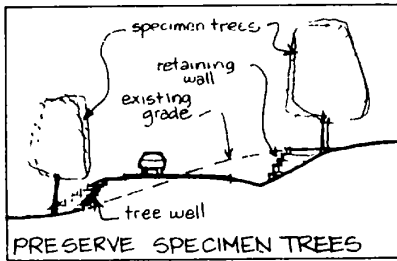


Fig. 4-25.

d. Utilize tree wells or retaining walls to preserve noteworthy specimen trees where cut and fill slopes would otherwise threaten the root system and survival of the tree (fig. 4-25).

2. Provide optimum conditions for revegetation of disturbed areas.

a. Follow proper fertilization, mulching and watering practices to encourage revegetation of disturbed areas.

b. Utilize proper planting techniques and planting seasons to promote revegetation and high survival rates of plant materials.

c. Consider planting holes or pockets and serrated slope edges on steeper cut and fill slopes to encourage revegetation and moisture retention on these slopes (fig. 4-26).

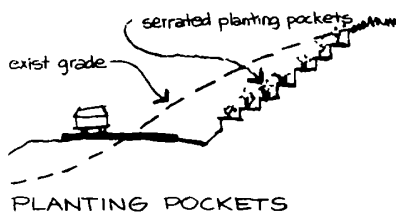


Fig. 4-26.

3. Revegetate disturbed areas to minimize their visual impact.

a. Use irregular or free-form clearing limits with undulating edges to vary the sequence of enclosure along the road; this adds

visual variety, promotes a natural landscape appearance and relieves visual monotony for motorists.

b. Feather edges with careful clearing of trees and shrubs to create a gradual transition of vegetation along the road, rather than a contrasting edge (fig. 4-27).

c. Encourage an informal mixture of native plant materials that will blend naturally with adjacent undisturbed vegetation.

d. Disperse new planting into undisturbed adjacent areas to reduce the contrast of the clearing edge.

Fig. 4-27.



Fig. 4-28.

e. Use massed plantings of appropriate size and form; avoid haphazard scattering as well as widely and regularly spaced planting that create a spotty appearance.

f. Use planting to emphasize positive visual elements, such as framing scenic views, and to minimize negative conditions, such as screening unsightly features.

4. Employ roadway planting

effectively for functional and safety-related uses as well as aesthetic ones.

a. Plant disturbed areas to minimize soil erosion and provide sediment control; follow proper soil erosion and sediment control practices during road construction.

b. Use planting to assist in driver guidance by delineating directional changes in the road alignment; planted edges make it easier for the driver to discern the outline of an oncoming curve (fig. 4-28).

c. Use planting to screen oncoming headlight glare.

d. Use planting to help control snow drifting onto the road.

e. Use planting to visually screen adjacent lands uses from road traffic.

C. Minimize Adverse Impacts of Roads on Adjacent Land Uses.

1. Air Pollution. Locate road alignments to minimize the impact of traffic-emitted pollutants on adjacent facilities.

a. Locate roads adjacent to land uses that are minimally affected by traffic-emitted air pollutants.

b. Reduce the impact of traffic emitted pollutants on more sensitive land use areas by providing planted buffers between them and locating roadways downwind of the prevailing wind pattern, especially summer winds.

2. Noise Pollution. The necessary abatement of excessive noise levels generated by auto

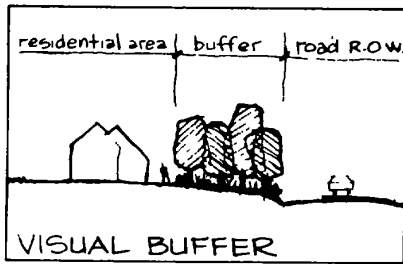


Fig. 4-29.

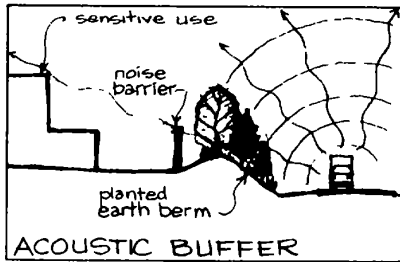


Fig. 4-30.

mobile and truck traffic should be taken into account when locating new roads or land uses; excessive traffic noise creates undesirable physical and psychological effects on people and their activities. (See TM 5-803-2, NAVFAC P-970 and AFM 19-10 for techniques to ameliorate the impact of vehicular generated noise, as well as that generated by aircraft, weapons and trains.)

a. Physically separate primary roadways from adjacent land uses whose normal functioning would be impaired by auto and truck traffic noise. Land uses considered sensitive to excessive traffic noise levels include:

- Residential areas
- Hospital and medical facilities
- Educational facilities
- Recreational facilities
- Religious facilities
- Administrative facilities
- Libraries
- Community facilities
- Child care facilities

b. Utilize noise abatement techniques such as earth berms,

sound walls and plant materials to reduce noise levels generated by traffic adjacent to sensitive land use areas (figs. 4-29 and 4-30).

c. Reroute truck traffic to roadways with less sensitive land uses adjacent to them; roadway noise nuisance is primarily associated with truck traffic.

4-5. Improve the Existing Network for Growth, Safety and Appearance.

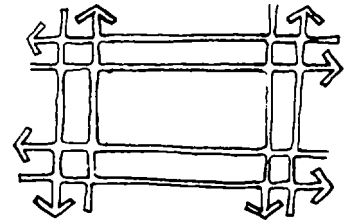
The existing road network of an installation should be improved as needed for growth, safety and appearance. This may entail network changes, removal of traffic hazards and enhancement of the streetscape.

A. Network Modifications.

Modify and improve the existing road network as needed to accommodate increased traffic capacity, facility expansion, control

of undesirable through traffic, or intersection safety and flow.

1. **Increasing Traffic Capacity.** Minimize the visual impact of necessary street improvements for increased traffic capacity.

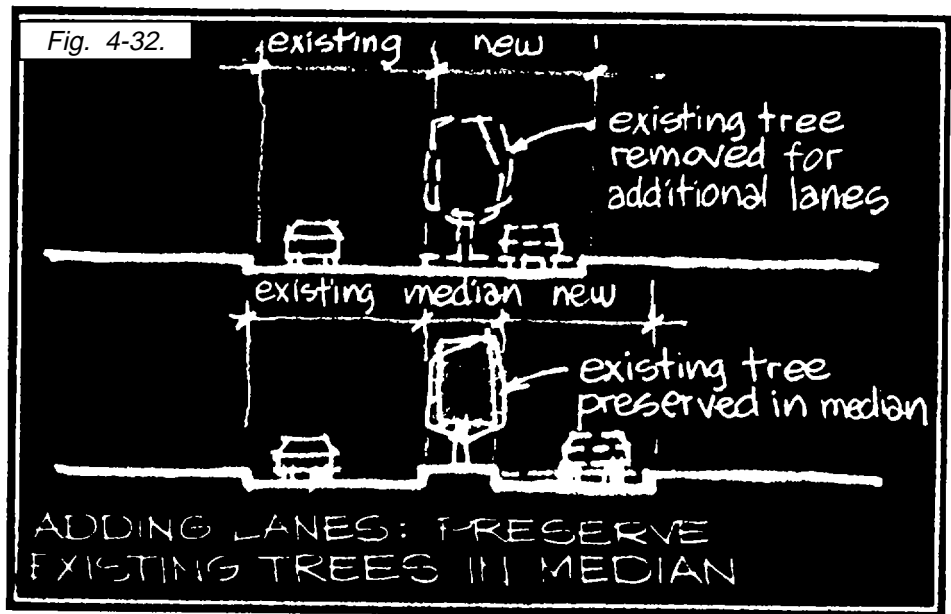


ONE-WAY COUPLET STREETS

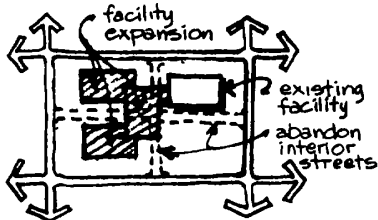
Fig. 4-31.

a. Create one-way couplet streets on adjacent parallel streets to increase traffic flow capacity without new road construction (fig. 4-31).

b. When adding lanes to an existing street to increase its capacity, use a center median between the existing road and the proposed new lanes to preserve existing street trees (fig. 4-32).



2. Accommodating Facility Growth. The introduction of a mega-block concept to accommodate either facility expansion or creation of a pedestrian precinct within a group of buildings that are presently separated by streets can be considered. Existing grid street systems that are undifferentiated and underutilized lend themselves to being converted to mega-blocks. Mega-blocks can be created by consolidating several blocks and utilizing existing perimeter streets more efficiently to enable abandoning interior street rights-of-way (fig. 4-33).



MEGA-BLOCK CONCEPT
Fig. 4-33.

3. Discouraging Through Traffic. Modify existing streets to discourage through traffic on local roads, especially in residential areas.

a. Convert a grid system into a series of internal loop roads that discourage through-traffic (fig. 4-34). This will also allow the creation of a central walkway where the existing grid system has been discontinued.

b. Convert a grid system into a series of internal cul-de-sacs that do not allow through-traffic (fig. 4-35). This may also provide additional home sites or a central walkway at the end of those streets that have been terminated.

4. Providing Safe and Attractive Intersections. Improve existing intersections as needed to provide safe and efficient traffic flow for both pedestrian and vehicular traffic.

Fig. 4-34.

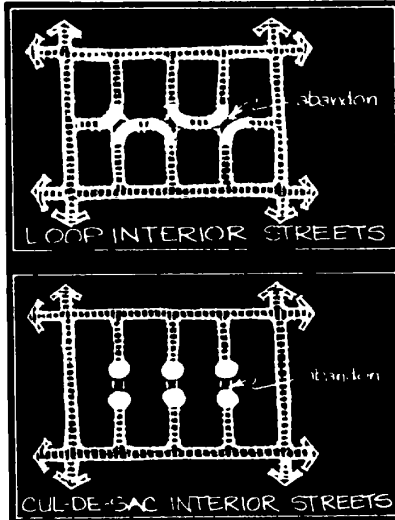


Fig. 4-35.

a. Introduce "T" intersections for tertiary road intersections with secondary or primary roads. This type of intersection has only three potential turning conflict points (as opposed to 16 at four-way intersections) and is particularly appropriate to reduce through-traffic and promote safety in residential and pedestrian areas (fig. 4-36).

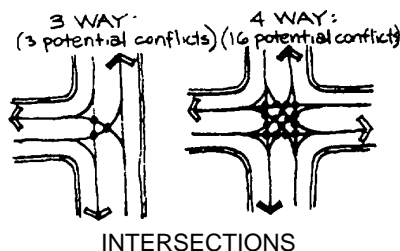


Fig. 4-36.

b. Provide turning lanes to eliminate interference with through-traffic flow at major four-way intersections (fig. 4-37).

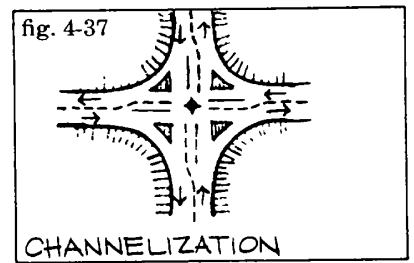


Fig. 4-37.

c. Provide safe pedestrian crosswalks at signalized intersections. (See Chapter 8: Walkways.)

d. Avoid complex intersections and correct existing ones. These type intersections include those with skewed approaches, jogged alignments, or with more than four approaches that create operational difficulties, safety hazards, decreased traffic flow capacity and unsightly large expanses of paving.

e. Connect parallel streets prior to an intersection with a major arterial or highway to minimize intersections with the major road (fig. 4-38).

f. Create local service drives paralleling a major road to provide access to individual abutting facilities while minimizing curb cuts along the main road which are unsafe and disruptive to traffic flow (fig. 4-39).

B. Removal of Traffic Hazards.

Remove and correct all existing traffic hazards along roads. Corrections of these deficiencies will often be justifiable on the basis of safety as well as appearance.

1. Inventory and Rank Traffic Hazards. Survey the installation to identify all potential traffic hazards and determine a priority listing of problems to be corrected based upon the severity of the hazard to personal safety.

2. Correct Unsafe Physical Obstructions near Streets.

Many of these obstructions, in addition to being unsafe, add greatly to the cluttered appearance of the streetscape.

a. Replace or correct culverts or headwalls that are too close to the street; provide protective curbing, guardrails and/or collision cushions.

b. Relocate signs, utility poles or fire hydrants that are too close to the street. In built-up areas, these should be no closer than two feet to the curb; along primary roads and highways these should be set back to a

Fig. 4-38.

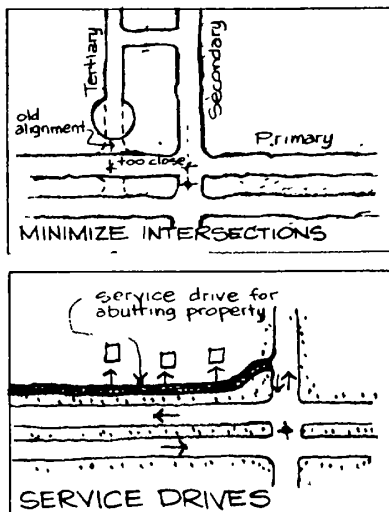


Fig. 4-39.

minimum of twelve feet from the edge of the pavement. Breakaway utility poles are desirable along highways.

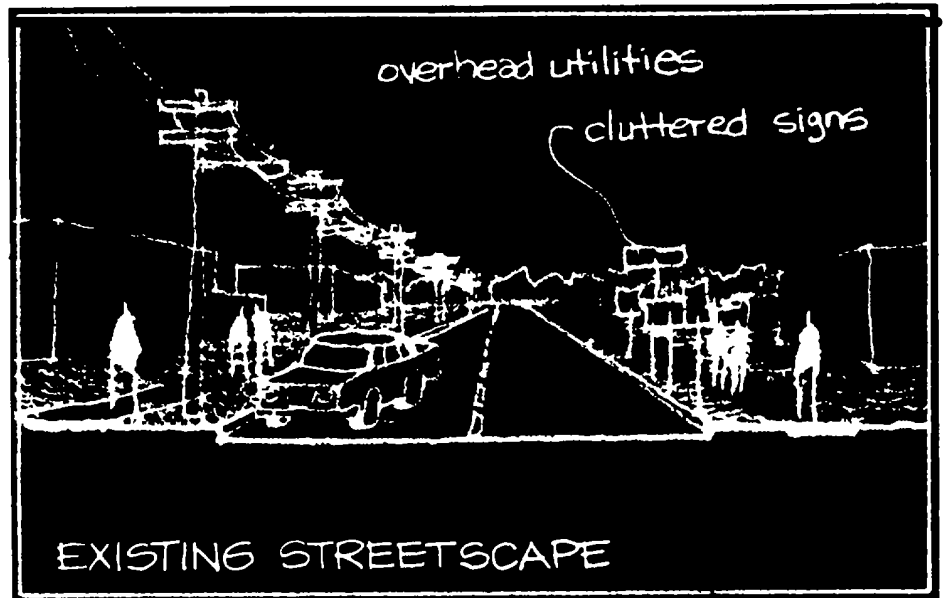


Fig. 4-40.



Fig. 4-41.

3. Correct Unsafe Physical Obstructions within the Roadway.

a. Provide curbing where necessary instead of using bollards, cones or guardrails.

b. The use of concrete median barriers that provide their own curbing are ideally suited for high-speed roads. These barriers should be continuous and their exposed ends should be detailed for safety.

c. Provide proper lighting and reflectors on potential roadway safety hazards.

C. Streetscape Improvement. Enhance the appearance of the streetscape by a coordinated design of its various components (figs. 4-40 and 4-41).

1. Minimize Streetscape Clutter.

Coordinate the design of streetscape elements to minimize clutter and provide an attractive roadway in keeping with its intended function and hierarchy in the overall network.

a. Planting. Consider planting as one of the simplest and most effective means of improving the visual quality of the installation's streetscape. Planting should be used to define the road hierarchy. Furthermore, planting should be used to screen headlight glare and to reduce the visual impact of adjacent surface parking lots and overhead utilities. (See Chapter 6: *Planting*; Chapter 5 *Parking*, and Chapter 13: *Utilities*.)

b. Lighting. Street lighting should be effectively used not only for public safety and security but also to strengthen the comprehension of the road hierarchy by varying the height, spacing and intensity of luminaires according to the type of road. (See Chapter 11: *Lighting*.)

c. Signing. Create a unified, coordinated and consistent streetscape signing system that provides direction and information in an effective and attractive manner. (See Chapter 10: *Signing*.)

d. Utilities. Bury utilities wherever possible to avoid their unsightliness and cluttering of the streetscape. The burial of existing utilities should be associated with the construction of new structures and the renovation or demolition of existing structures. Where overhead utilities along the street are unavoidable, use trees and topographic features to minimize their visual impact. (See Chapter 13: *Utilities*.)

e. Street Furniture. Use a coordinated and unified design of functional street furniture along the streetscape, employing multi-use clustering of elements wherever possible to reduce clutter. (See Chapter 12: *Site Furnishings*.)

f. Paving. Use special paving to differentiate between pedestrian and vehicular areas, articulate areas of pedestrian and vehicular conflicts and indicate directions or controls in the circulation network. Paving designs such as at crosswalks should be consistent in design and application (See Chapter 8: *Walkways*.)

2. Curbs and Gutters. Use a consistent design and application of curbs and gutters (fig. 4-42).

a. Use curbs and gutters to define the road edge and channel storm drainage in more densely developed areas of the installation.

b. Where density is relatively low or in rural areas, avoid curbs and gutters in favor of drainage swales or ditches that blend into the natural landform.

c. Provide necessary curbs with a unified design, avoid inconsistent or scattered applications of curbs and gutters within developed districts of the installation.

3. Medians. Use medians to safely separate or channel traffic, to reinforce the circulation hierarchy of the road network

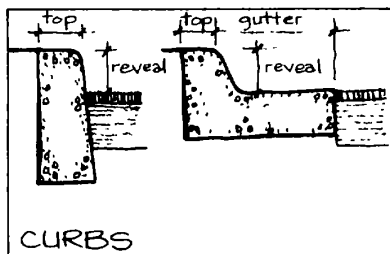


Fig. 4-42.

and to provide safety islands for pedestrians at wide street crossings; provide appropriate planting of medians to visually reinforce the road hierarchy and minimize maintenance.

a. Grass can be used attractively in medians, but usually requires frequent mowing to be maintained.

b. Ground cover, such as ivy, requires little maintenance but tends to catch litter when used in medians.

c. Trees and shrubs with bark ground cover can provide both an attractive and relatively maintenance-free median if the bark can be controlled from scattering onto the road.

d. Concrete or paved medians tend to be utilitarian and relatively maintenance-free medians best suited for pedestrian areas; in other areas they can be unattractive if not combined with street trees.

e. Consider the possibilities of historic military equipment displays or flagpoles along medians to visually highlight special areas such as main entrances to the installation. However, care should be exercised in the design of these displays to avoid a cluttered appearance.